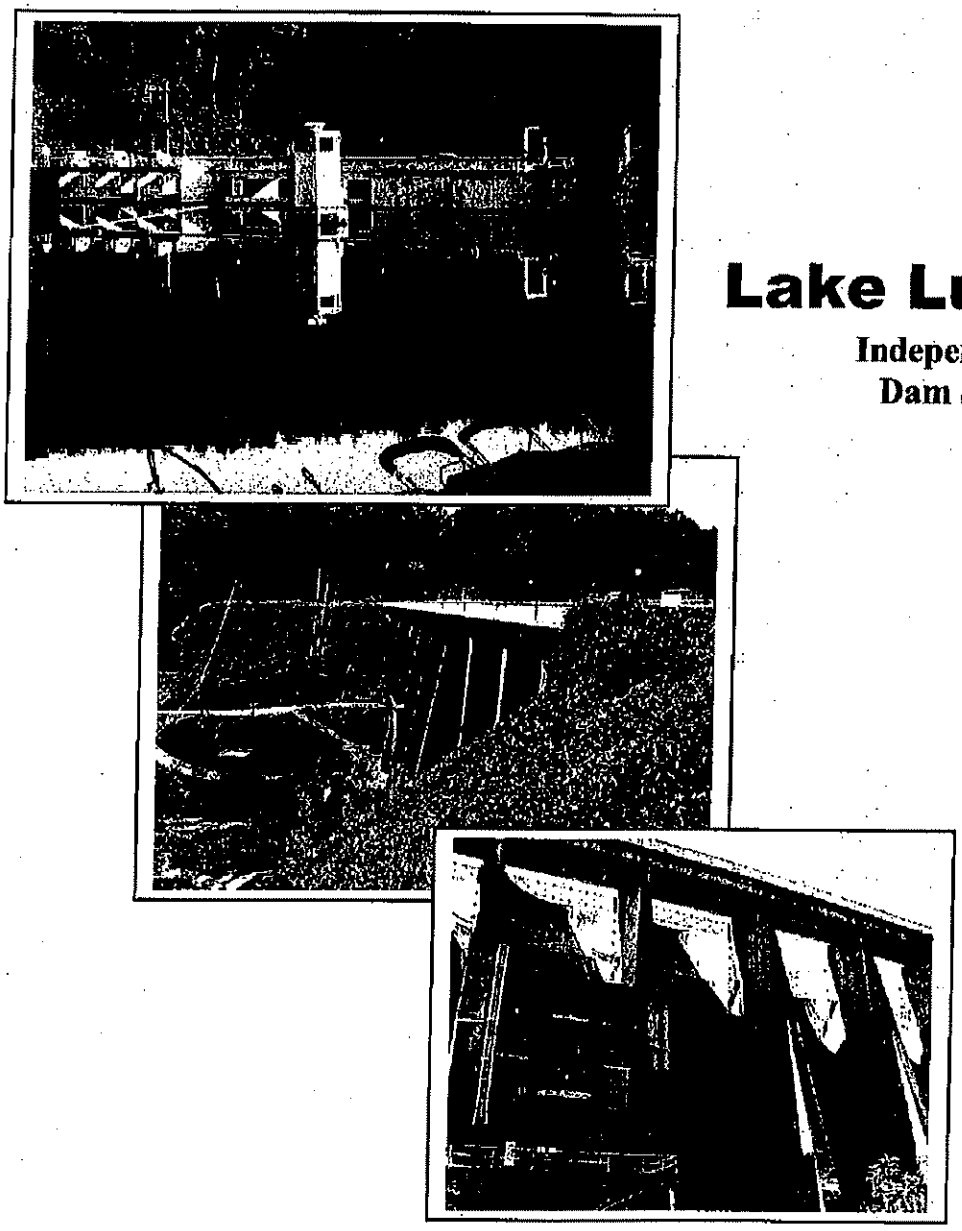
DTA

Devine Tarbell & Associates, Inc.
Consulting Engineers, Scientists, & Regulatory Specialists



Lake Lure Dam

Independent Consultant
Dam Safety Inspection
November 2006

Prepared For:

Town of Lake Lure
North Carolina

Section 1 - INTRODUCTION

The Town of Lake Lure owns and operates the dam that impounds the Broad River to form Lake Lure. The dam includes an intake and penstock that supply water to a hydroelectric station located immediately downstream of the dam. Lake Lure Dam is a multiple-arch concrete configuration with nine arch bays and three ogee shaped gated (radial steel Taintor gates) spillway bays. The dam was constructed in 1925-1926 with no significant structural changes since that time. A bridge deck and local traffic highway cross the bridge.

The dam was reportedly designed by the engineering firm of Mees and Mees of Charlotte. Dam construction was completed in September 1926 with the Lake being completely filled in 1927. At full pond, Lake Lure has a surface area of 720 acres with approximately 27 miles of shoreline. The hydroelectric facility began commercial operation in 1928, and is currently supplying power under contract to Duke Energy. The powerhouse contains two vertical shaft generating units (1200 and 2200 kilowatts) with Francis type turbines. The power station and dam are not regulated by the Federal Energy Regulatory Commission.

It is understood that the dam has performed well during its service life. Maintenance activities have been confined primarily to the powerhouse equipment, intake gate and spillway gates. No significant concrete structural modifications or repairs have reportedly been performed during the life of the structure.

The Lake Lure Dam falls under the dam safety regulatory oversight of the North Carolina Department of Environment and Natural Resources: Division of Land Resources – Land Quality Section. Representatives of the Land Quality Section conduct periodic inspections of the dam. Personnel from that office inspected the dam on March 30 and June 29, 2006. Their June 30, 2006 letter to the Town of Lake Lure directed that "The Town shall take action to address necessary maintenance and renovations for the dam". Additionally, the letter required that the Town secure the services of "A qualified Dam safety engineer familiar with large concrete structures shall provide plans and supervise all activities". Maintenance problems noted in the letter included:

- Seepage on many areas of the dam
- Spalling of concrete surfaces
- Exposed reinforcing bars in several areas

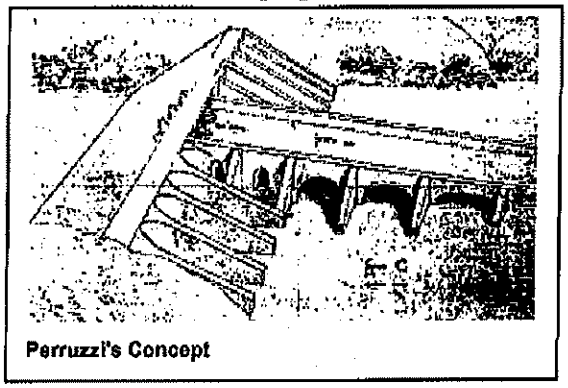
This report presents the observations, conclusions and recommendations made for the inspection which was conducted by Edwin C. Luttrell, P.E. of Devine Tarbell and Associates Inc. Conclusions are subject to the inevitable practical limitations on the scope of information that was available and the limitations of a visual examination.

Section 2 – MULTIPLE-ARCH DAMS

Lake Lure Dam is a multiple-arch type dam, one of the family of buttress dams. Buttress dams (flat slab-Ambursen, massive head and multiple-arch) use cantilevers, slabs, domes or arches to transfer the force of the water to vertical buttress elements which in turn transfer load to their foundation. The elements between the buttresses are typically inclined. These differ from gravity dams where the dams own weight is required to resist the thrust of the water. The principle advantage of buttress dams including multiple-arch configurations is the reduced amount of material needed and the ability to safely utilize a more diverse range of foundation conditions.

The earliest examples of the use of buttresses can be seen in Roman dams built in what is now Spain. The Romans were the first civilization to incorporate concrete and mortar into the construction of dams. An 18 ft high masonry dam built by the Romans in the Iberian peninsula near the village of Esparragalejo included buttresses 28 feet apart with the wall sections between the buttresses curved making it a forerunner to the modern multiple-arch dam. Around 1530, the architect Baldassare Peruzzi proposed a multiple-arch design to dam the River Bruna near Siena, Italy. Later examples of multiple-arch buttress type structures were built in the 1700's near Bilao, Spain.

Esparragelejo



Perruzzi's Concept

Spaniard Don Pedro Bernado Villerreal de Berriz wrote the first book on the design of dams in 1736. In this book the theory of using buttresses to support a series of arch sections was proposed. He proposed vertical faces which fail to take advantage of water loading on a sloping face to enhance stability.

The development and application of the reinforced concrete multiple-arch dam design similar to Lake Lure Dam in the United States was pioneered by John S. Eastwood in California in the early 1900's. Eastwood's first design to be built was the Hume Lake Dam. In addition to using the relatively new technology of reinforced concrete, additional features included the inclined upstream face transitioning to what Eastwood termed the "vertical head" at the top of the arches where water loads were smaller. The basic premise was that all

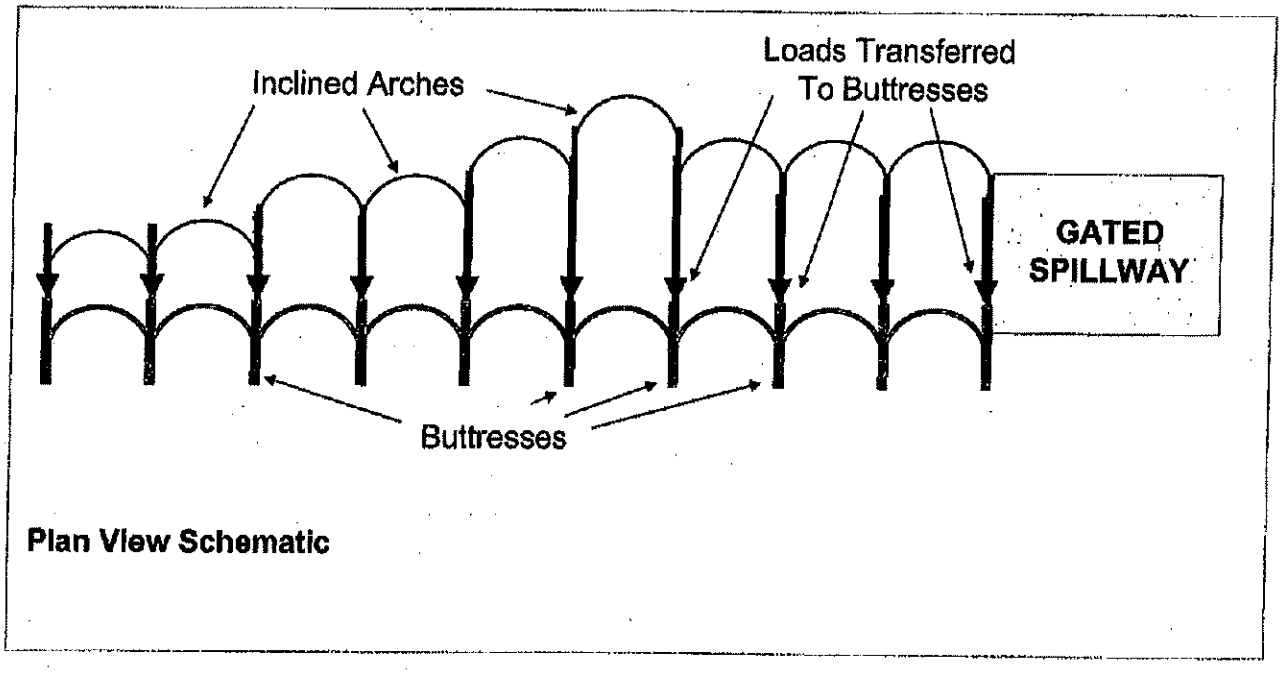
Hume Dam (1806)

elements of the structure would be in compression and that the water load was in part acting downward, reducing the need for structure weight to create stability as found in a gravity section. It was estimated that this configuration reduced construction costs by 30 percent – 40 percent. Eastwood went on to construct over fifteen multiple-arch dams prior to 1925, all of which are still in service, none having failed. Over 60 multiple-arch dams have been constructed in the United States, the last in 1965. With the exception of an early structure in California constructed on poor foundation with inferior masonry materials, none have failed in service.

While there is not a known direct link to Eastwood, it seems clear that the Lake Lure Dam (and Turner Shoals downstream) followed the design concepts advanced by Eastwood.

One limitation of all buttress dams, including the multiple-arch variant, is that a lack of lateral stability is inherent in the design. This is would only be significant in areas with significant seismic hazard. No multiple-arch dam has failed in the west due to earthquake shaking; however a number of structures have been strengthened to enhance seismic stability.

The sketches below demonstrate the basic concept behind the multiple-arch structure. Water loads are transferred to the vertical buttresses at each arch bay. This thrust load produces compressive stresses in the buttresses that are resisted by vertical and horizontal reactions at the foundation contact. Inclining the arch sections produces a component of the water load acting vertically, reducing the forces trying to cause the dam to slide downstream.

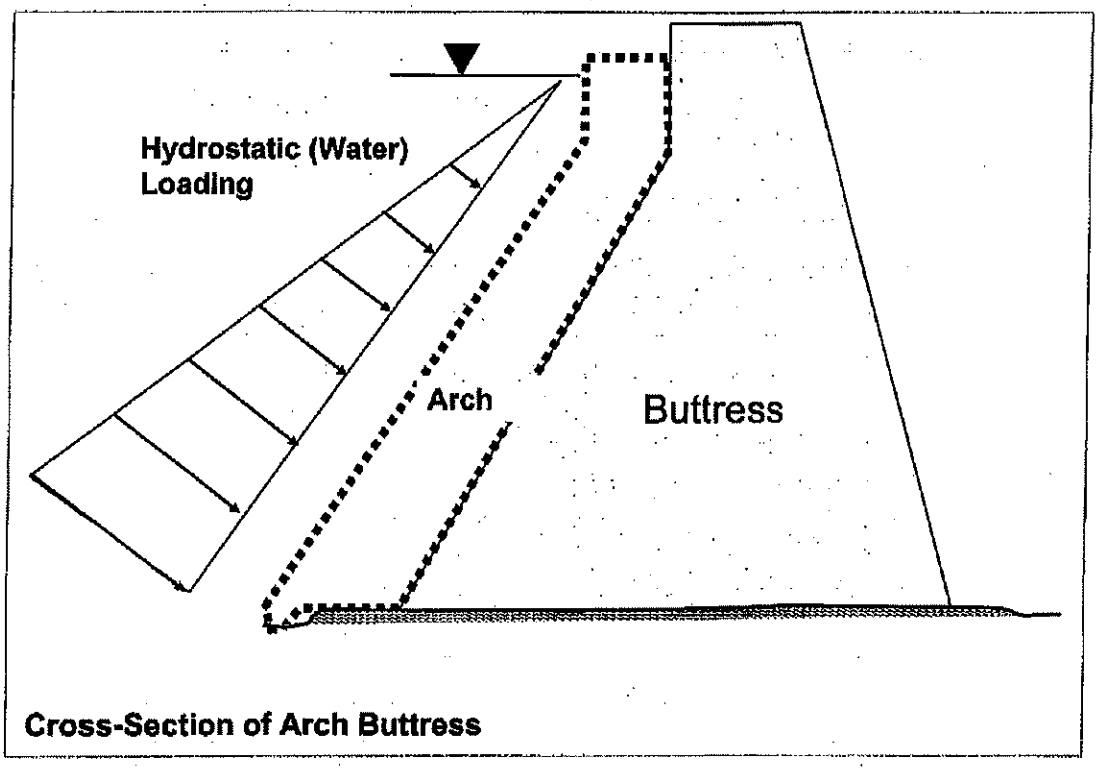


Plan View Schematic

Section 2 – MULTIPLE-ARCH DAMS

Analyses of structures similar to Lake Lure Dam have verified that tensile stresses are negligible for static loading cases. The amount of reinforcing is not known (no drawings found) but the lack of cracking typical in unreinforced concrete suggest that at least temperature reinforcing was utilized. Cracks at the arch/buttress interface suggest that a structural connection exist at that location.

No stability or stress analysis is known to have been performed for Lake Lure Dam. Global stability computations for multiple-arch dams are performed similar to those for gravity sections. In addition the stresses within the arch elements and buttress are



Cross-Section of Arch Buttress

evaluated. The Independent Consultant has reviewed calculations for very similar structures which demonstrated adequate stability including relatively low compressive stresses in the arch and buttress sections. This would indicate that limited surficial damage to concrete would not have serious consequences relative to stability and safety.

The multiple-arch design results in safe and reliable structures assuming the structure is maintained, that adequate foundation conditions are present and compentent construction materials were utilized. The foundation of the Lake Lure Dam appears to be a competent rock foundation based on observation of the surrounding terrain.

Section 3 – FIELD INSPECTION

An inspection of the Lake Lure Dam was completed on October 18, 2006 by the Independent Consultant, Ed Luttrell, P.E. accompanied by Chuck Place, Lake Lure Town Manager, William Grimes, Dam Superintendent and Ron Morgan, Lake Lure Fire and Emergency Management Coordinator. The weather at the time of the inspection was excellent with sunny and warm conditions. At the time of the inspection Lake Lure was at approximately normal full pond elevation. The lake is typically maintained in the top six to nine inches below full pond to support the strong recreation and homeowner aspects of the lake.

The inspection included a review of available documentation consisting of a limited number of original construction drawings as well as letters summarizing inspections by the State of North Carolina. No detail drawings showing reinforcement were available. The Dam Superintendent provided additional information in an interview and during the field walkdown. A copy of the Emergency Operations Plan (Ordinance Number 99-10-21) and the Lake Lure Dam Emergency Action Plan (EAP) dated November 1999 was reviewed.

A visual inspection of the dam was performed by walking the bridge deck, from the left (downstream) abutment and by accessing the downstream arch bays from the powerhouse to the right abutment. The arch bays located to the left of the tailrace and powerhouse could not be safely accessed for close-up review and could only be observed at distance.

Bridge Deck

The bridge deck is in relatively good condition with some cracking of the concrete and weathering damage apparent. The bridge only sees moderate to light volumes of traffic and appears to be structurally sound. A comprehensive structural inspection was beyond the scope of the dam inspection and was not performed.

Radial Gates

The three steel frame radial gates (Photographs 2,6 and7) are in good condition and reported to operate well. Maintenance, including new seals was performed in the mid 1980's. The gates are operated to prevent the elevation of Lake Lure from rising significantly above full pond and to route significant storm events. Each gate has a dedicated hoist with a single lift chain which connects/wye's to cables attached to each side of the base of the gate. The coating of the gates is in good condition. Leakage was occurring, but was not excessive and seemed concentrated at the gate corner where the bottom and side seals intersect. This is a common location for some leakage to occur in this type gate. Some vegetation is growing on steel cross members and should be removed to protect the coating system and facilitate observation.

Section 3 – FIELD INSPECTION

Intake Structure

The intake to the hydroelectric station (Photograph 3) is a vertical concrete tower with a steel cylinder gate. The intake was observed from the bridge deck. No evidence of structural distress was observed. The cylinder gate is not normally operated and there was reportedly difficulty opening it the last time it was closed. The gate reportedly could be closed in an emergency.

Arch Bays

Arch bays located to the right of the powerhouse were inspected by entering each bay from the downstream side. Minor leakage and efflorescence was observed at the lift lines (horizontal boundaries between successive concrete pours) and at the base of the arch. Reportedly, leakage does not vary significantly with seasonal changes in air and water temperature. Portions of the arch concrete was obscured by vegetation (Photograph 15) and the arch bays located to the left of the powerhouse could only be observed from the bridge deck, left abutment slope and from a significant distance downstream. There were no observed instances of structural distress such as severe cracking, deformation or misalignment. Cracking is present at the top of the arch/buttress interface (Photograph 5). At a number of locations, spalled concrete is exposing steel that may be reinforcing steel as well as additional steel associated with supporting original formwork.

Buttresses

The buttresses were examined from accessible vantage points. The concrete was in very good condition for its age. Given the exposure to moisture and freeze-thaw cycles, the amount of surficial deterioration is surprisingly low, given it is likely that the concrete did not have air entrainment. At several locations, steel is protruding from the surface of the concrete; most of it appears to be carrier steel used to support the formwork for the arch sections. At several locations, spalled concrete is exposing steel that may be reinforcing steel or additional steel associated with supporting original formwork.

Powerhouse

The powerhouse (Photograph 14) is a concrete and brick masonry structure. It is in good condition for its age and both generating units are operable. The powerhouse is structurally independent from the dam.

Abutments

The abutments were covered in very dense vegetation, mostly kudzu (Photographs 11, 12 and 13). There was no evidence or serious erosion or significant seepage at either abutment. The retaining wall along the left (facing downstream) abutment appears in good condition with no evidence of misalignment or other structural defects.

Section 4 – CONCLUSIONS & RECOMENDATIONS

The Lake Lure Dam was determined to be generally in good condition based on visual inspection and evaluation as discussed in this report. The dam is generally well maintained by the Town staff. No items were noted that would suggest the safety of the structure has been compromised, or that immediate actions to assure project safety are required. Some leakage, near surface concrete deterioration and cracking was observed but these conditions do not appear to be substantially worse than conditions described in previous inspection reports (DE&S 1999).

The emergency action plan (EAP) is appropriate given the consequences of a dam failure. The commitment to emergency preparedness by Town staff is commendable. The EAP should be kept updated with current communication information. It would be prudent to revise the inundation maps if development downstream has changed significantly since the maps were developed.

RECOMMENDATIONS

1. Clear the vegetation (ivy, kudzu etc.) that is obscuring the arch concrete and buttresses in several bays. Herbicides may not be fully successful, necessitating mechanical removal.

2. Develop a means for personnel to safely access the arch bays and spillway sections located to the left (looking downstream) of the powerhouse and tailrace. Possible options include stairs or ladder from the left abutment or a walkway on the pipe crossing.

3. Formalize the visual inspection by the operations staff. These formal inspections should be conducted at least quarterly. Inspections should be documented on inspection checklists/logs similar to what is provided in the Emergency Action Plan. These inspections should take careful note of any concrete deterioration and changes in concrete condition over time. Observation notes can be supplemented with digital photographs.

4. Retain a qualified dam safety engineering consultant to conduct a comprehensive visual inspection in two years (by 31DEC08). This inspection should include close examination of all arch bays including those to the left (looking downstream) side of the powerhouse and areas currently obscured by vegetation. If concrete deterioration has advance in extent and depth or if significant areas are present where reinforcing steel is exposed, concrete repairs should be considered at that time. If no progression in concrete condition is noted, similar independent consultant inspections from that point should be conducted at five year intervals.

Section 5 – REFERENCES

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Jackson, Donald C. Building the Ultimate Dam: John S. Eastwood and the Control of Water in the West. Norman, OK. University of Oklahoma Press. 2005.

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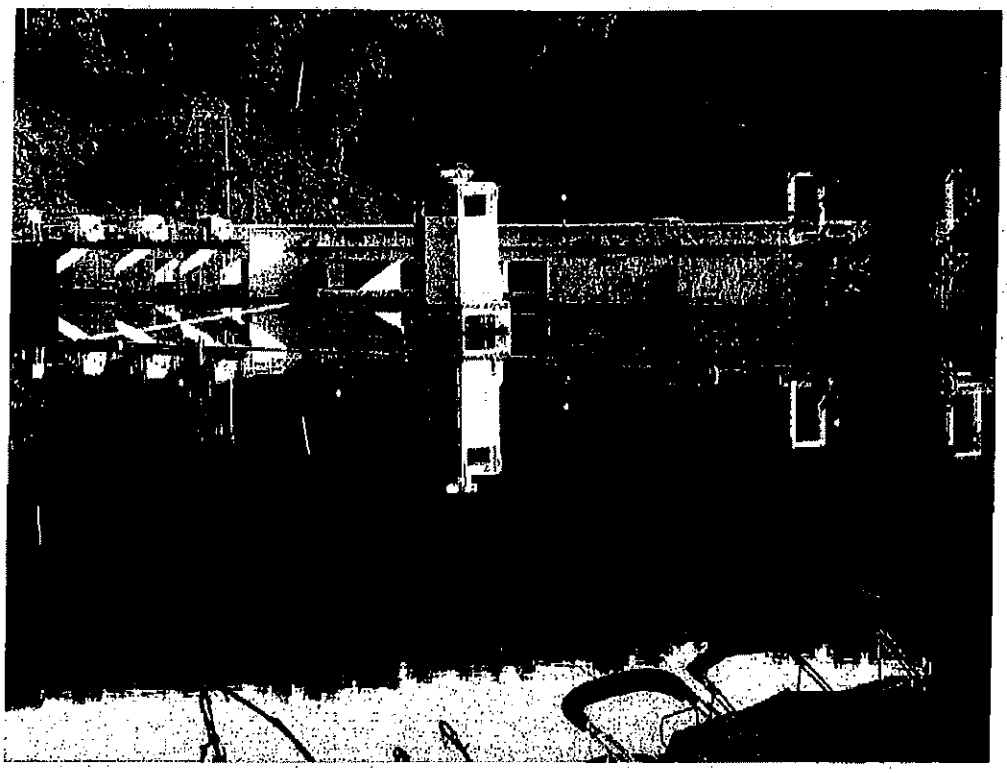
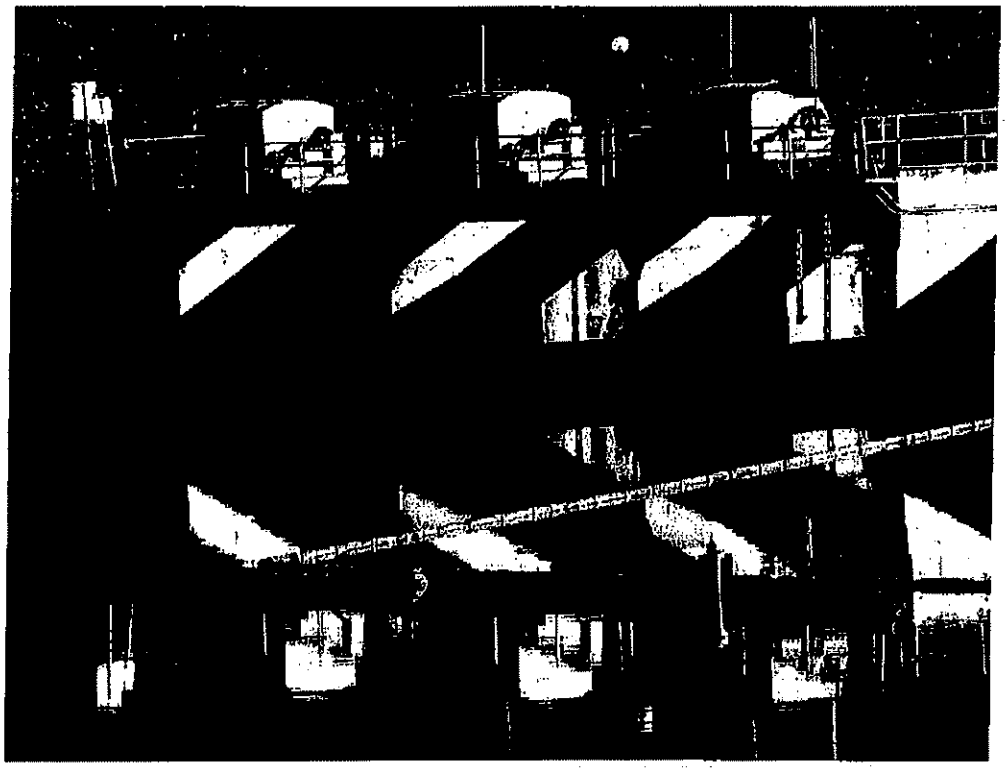
GEI Consultants Inc. "Emergency Action Plan: Lake Lure Dam." November, 1999.

APPENDICES

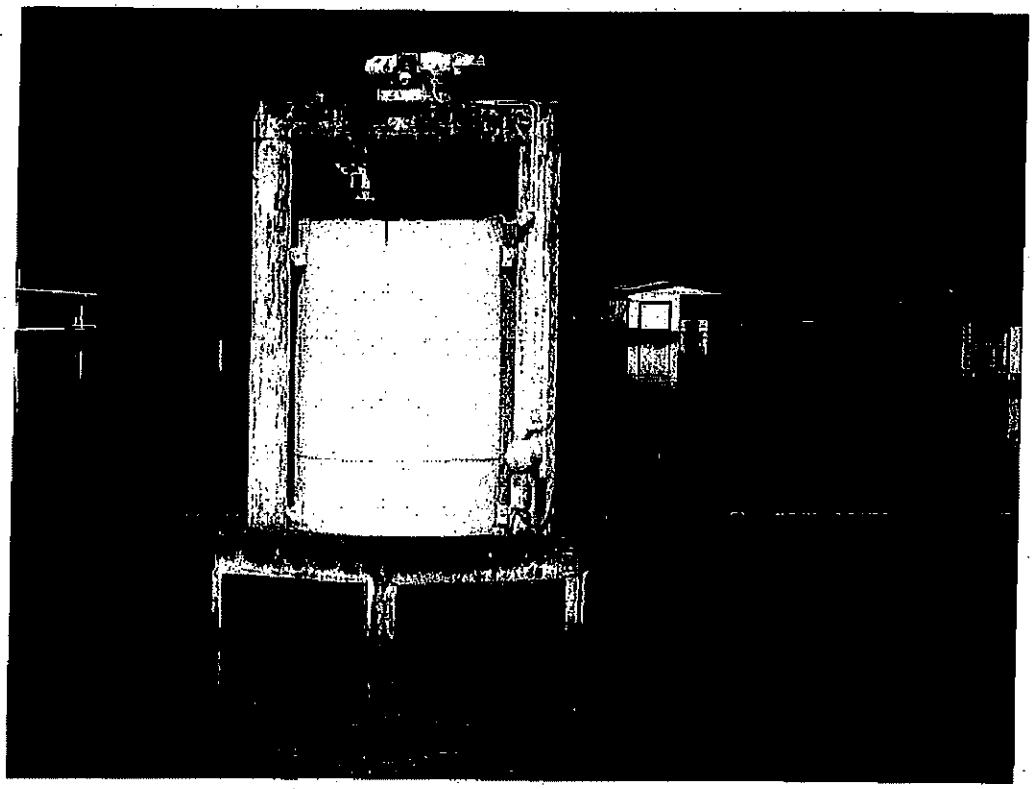
- Photographs
- Independent Consultant's Resume
- Letters



Photograph 1 Upstream View

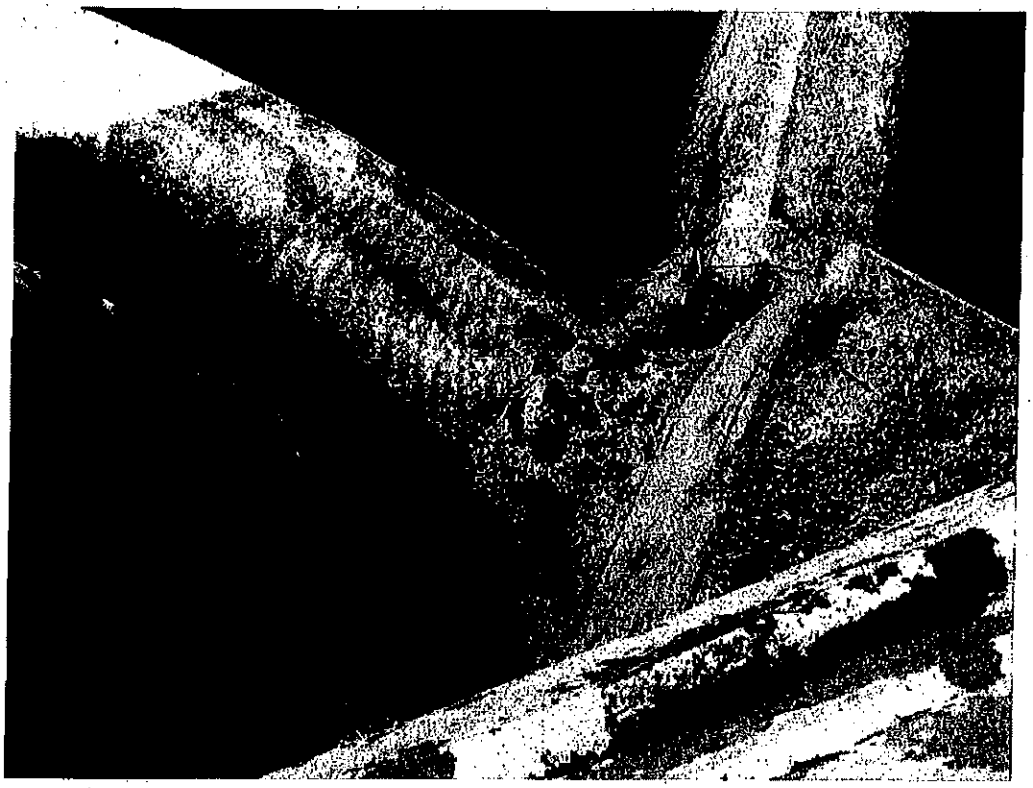


Photograph 2 Spillway Gates



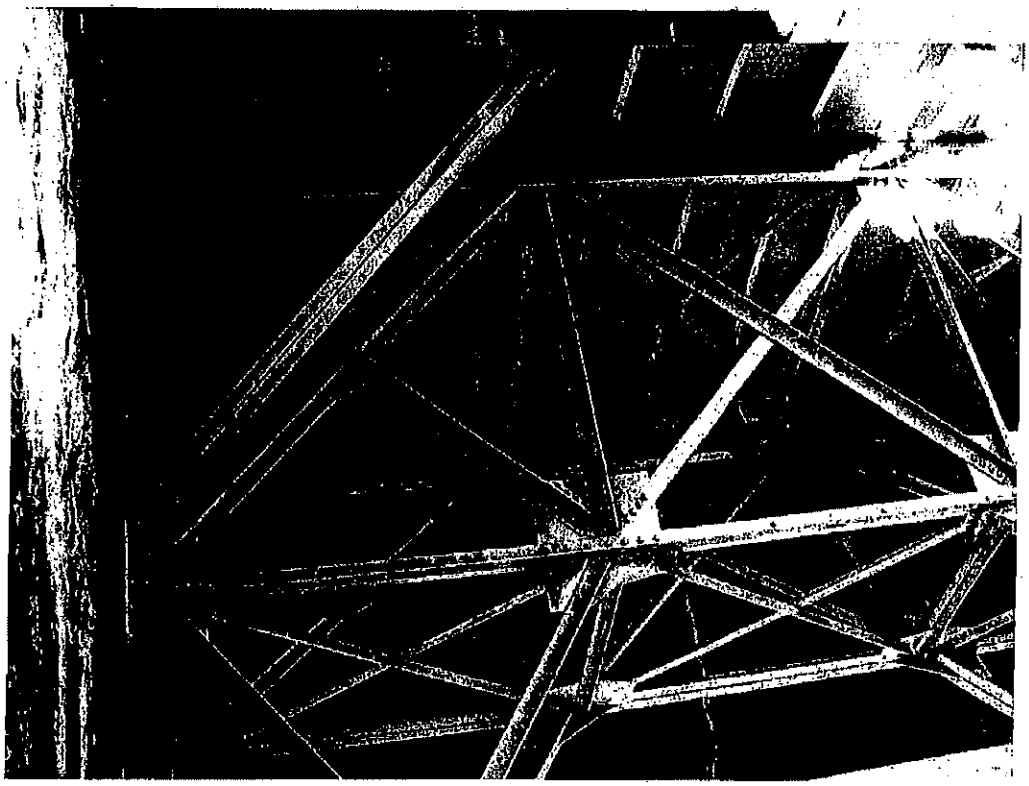
Photograph 3 Intake and Cylinder Gate

Photograph 4 Vertical Arch Section



Photograph 5 Arch/Buttress Interface

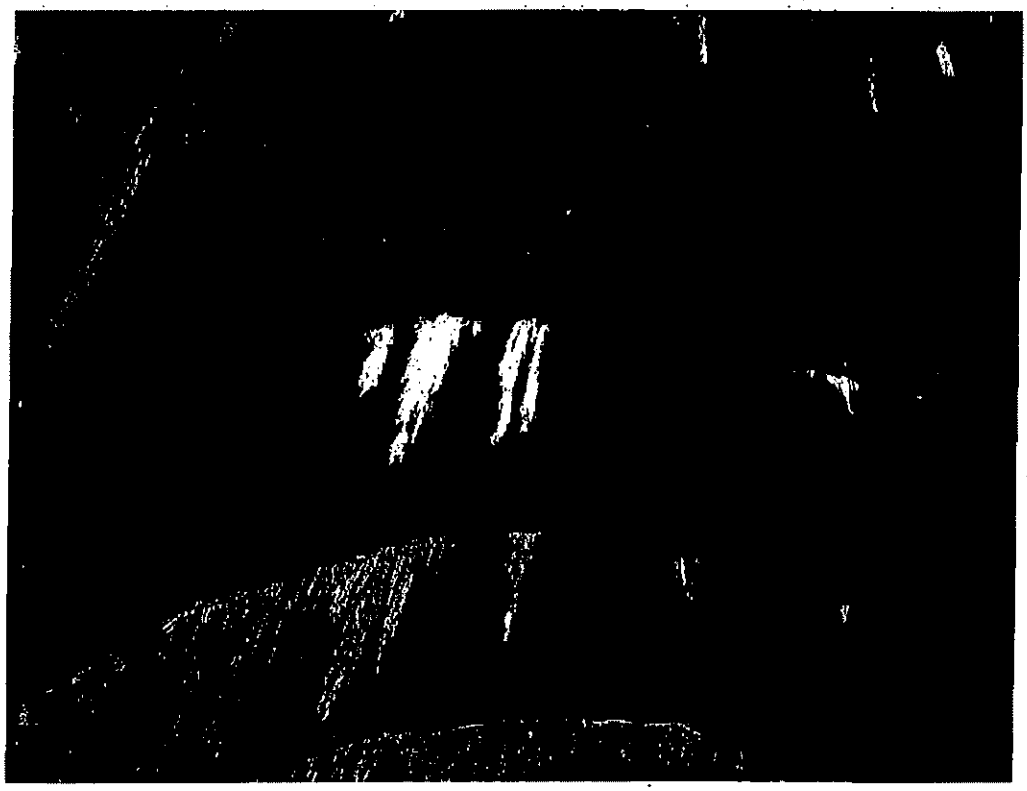
Photograph 6 Gate Hoist



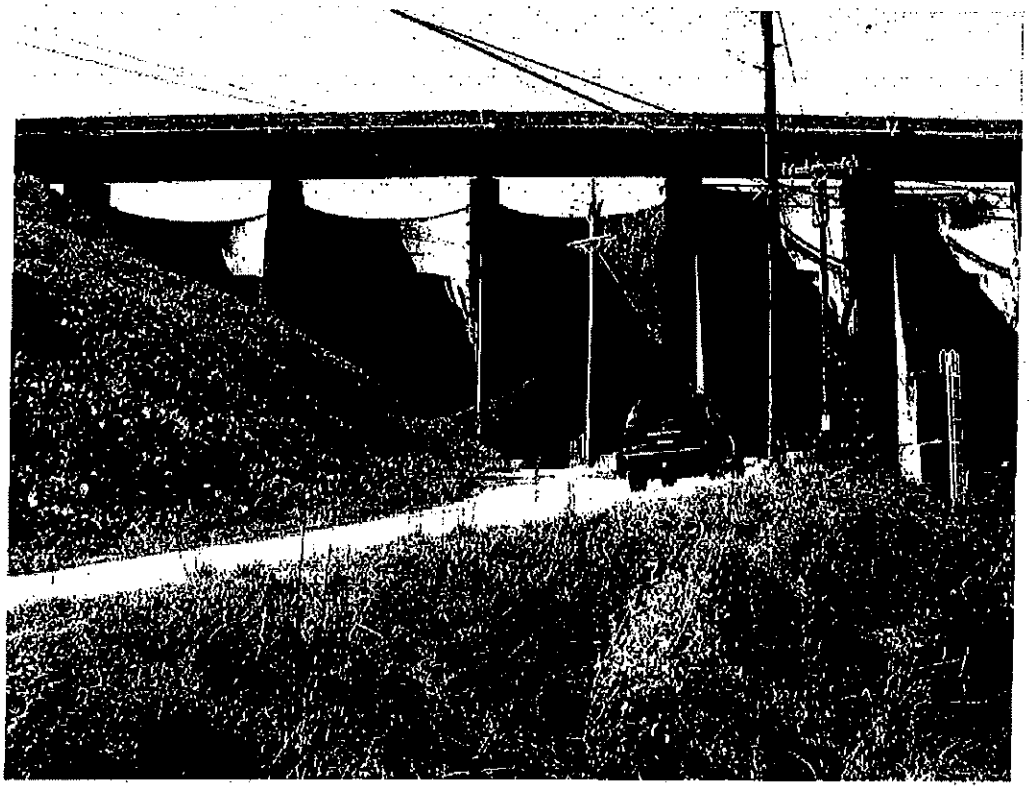
Photograph 7 Spillway Gate

Photograph 8 Downstream

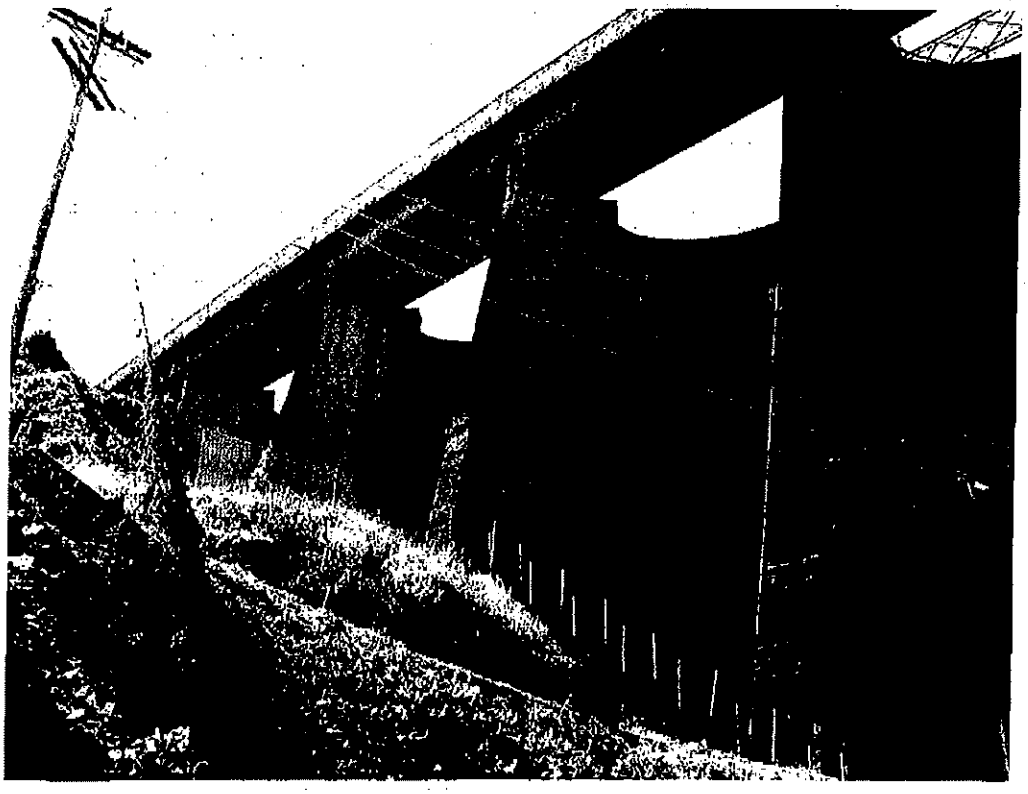
Photograph 9 Typical Arch Barrel (Bay)



Photograph 10 Efflorescence at Lift Joints

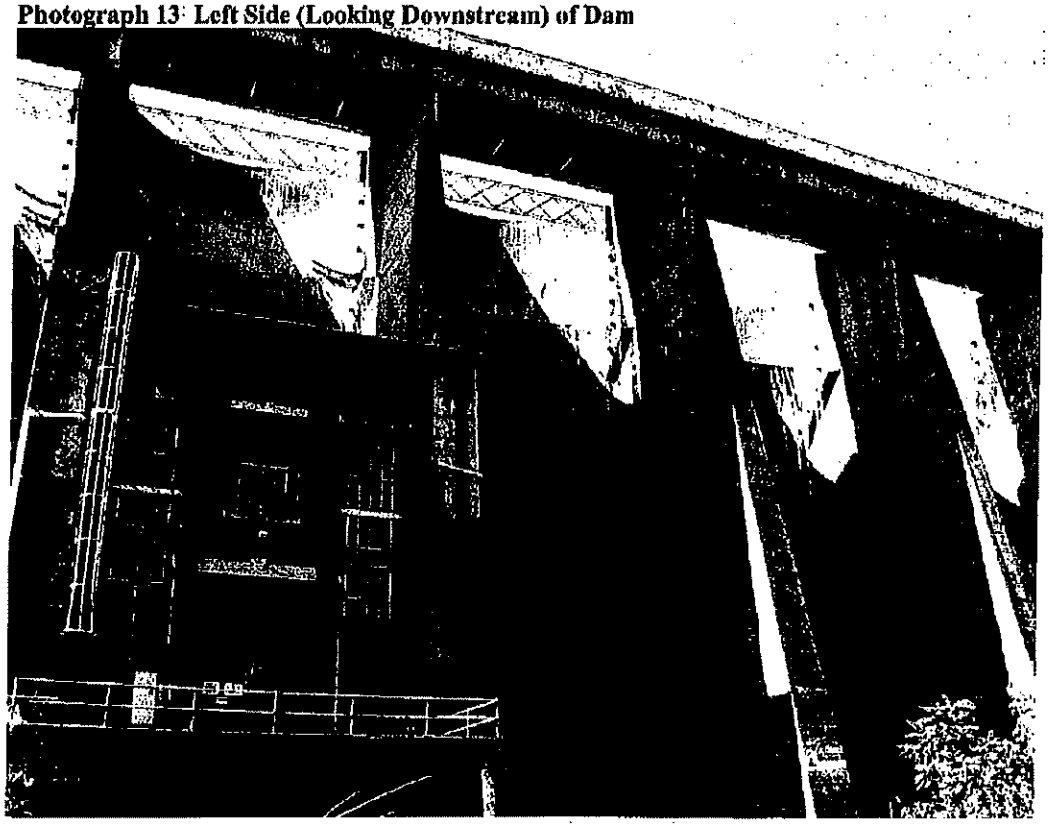


Photograph 11 Arch and Buttress Sections



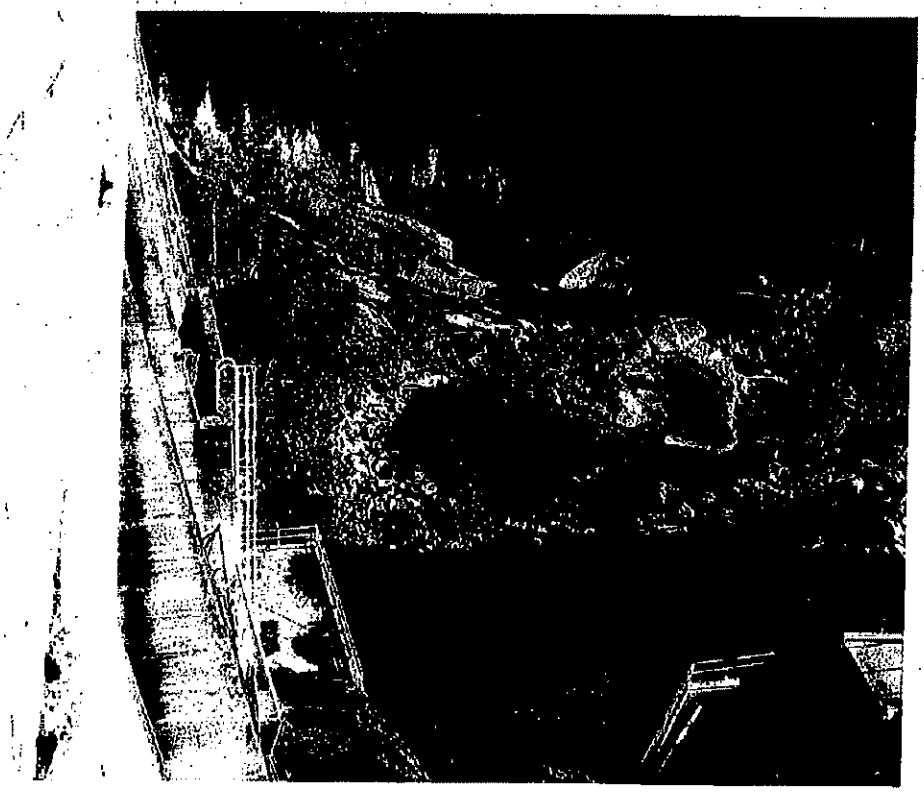
Photograph 12 Buttress Piers

Photograph 13 Left Side (Looking Downstream) of Dam



Photograph 14 Powerhouse

Photograph 15 Vegetation Obscuring Concrete



Photograph 16 Area Without Safe Access

Consultant Resume and Experience Matrix

Devine Tarbell & Associates, Inc.
Consulting Engineers, Scientists, & Regulatory Specialists

Edwin C. Luttrell P. E.
Principal – Southeast Region

Education

BSCE, University of Kentucky
Post Graduate - Univ. of S. Carolina

Registrations and Professional Affiliations

Professional Engineer
United States Society on Dams
Association of State Dam Safety Officials
National Hydropower Association
RAM-D Licensee
FERC DSPMP & PFMA Training Program

Key Qualifications

Mr. Luttrell has 25 years experience in project management, licensing, engineering design, inspection, operational support, and analysis of dams and energy facilities. He has led and/or participated in the technical condition inspection/evaluation of over 150 hydroelectric facilities including assessment of dams and other principle features. Mr. Luttrell has conducted FERC Part 12 inspections and participated as a facilitator and licensee representative core team member for the new PFMA process. His diverse experience includes the inspection, analysis and design of gravity dams, arch dams, embankment dams, spillways (gated and overflow), powerhouses, canals and water conveyance system (tunnel, steel penstock, wood penstock). Mr. Luttrell's experience includes planning, design and operations aspects of pumped storage hydroelectric projects. His experience includes project management, group facilitation, study execution and document development for FERC hydro licensing. Mr. Luttrell has been involved in design studies and evaluations for hydroelectric facilities in the United States, Argentina, Belize, Bolivia, Brazil, China, Costa Rica, Mozambique, Nicaragua, Peru, Indonesia, Thailand, Turkey, and Zambia.

RELEVANT PROJECT EXPERIENCE

FERC Part 12, East Fork Hydroelectric Project – Core team member for the Part 12 and PFMA process for this three development project. Prepared the complete supporting technical information document (STI) as required in Chapter 14 of the FERC Engineering Guidelines. Coordinated completion of filed inspections and responsible for final review of PFMA and Part Independent Inspection report.

FERC Part 12, Pinnacles Project – Approved as the Independent Consultant for the 2004 Part 12. Approved independent consultant in the completion of the Part 12 inspection. Prepared drafts of IC reports, participated in field inspection, reviewed project documentation and reviewed project design documents for arch dams and wood-stave penstock.

FERC Part 12 / PFMA, Claytor Dam – Facilitator for the Potential Failure Mode Analysis for AEP's Claytor Dam. Role as defined by the new FERC Part 12 process (Chapter 14 of FEG).

Catawba–Wateree Hydroelectric Project – Project Manager for FERC relicensing support for this 11 development project (825 MW). Support includes document preparation, strategic issue review, operational modeling and study planning. Serves as the only external member of the owners licensing core team.

Nantahala Hydroelectric Project – Project Manager for FERC relicensing support for seven projects. Support includes license application preparation, strategic issue review, operational modeling and resource studies. Serves as the only external member of the owners licensing core team.

Completed inspections of the projects that include gravity, rockfill and arch dams.

FERC Part 12, Parr & Fairfield Projects – Approved as the Independent Consultant for the 2006 Part 12. Approved independent consultant in the completion of the Part 12 inspection. Preparing drafts of IC reports, participated in field inspection, reviewed project documentation and reviewed project design documents for embankment and concrete gravity dams. Addressed extensive instrumentation monitoring program. Prepared Project STI's.

Five Year NCUC Inspection, Tuxedo Project – Completed five year independent consultant inspection for the Tuxedo Hydro Project. Five year North Carolina Utilities Commission inspections are completed following a process and outline comparable to the FERC Part 12 process. The Tuxedo project includes a powerhouse, wood-stave penstock and concrete arch dam.

ElectroLima(EDEGEL), Lima, Peru - Part of the technical due diligence team evaluating five high-head hydroelectric projects with a total capacity of 600 Mw. Responsible for the civil and environmental condition assessments including the development of twenty year O&M and capital expenditure profiles. Completed dam safety evaluations including design review of the 50 m high Yuracmayo Dam during the construction phase. Inspected extensive tunnel, canal and steel penstock water conveyance systems.

FERC Part 12 / PFMA, SCE&G Saluda Dam – Approved Part 12 Independent Consultant for the Saluda Project in South Carolina. This project is undergoing a major seismic remediation. Mr. Luttrell is the approved Part 12 Independent Consultant for this project.

FERC Part 12 / PFMA, West Fork Project – Facilitator for the Part 12 Potential Failure Mode Analysis. Role is as defined by the new FERC Part 12 process (Chapter 14 of FEG). Also responsible for the preparation of the Supporting Technical Information document for this two development project. Project features include a large earth dam, concrete arch dam, tunnels and penstocks.

FERC Part 12 / PFMA, Bear Swamp Pumped Storage Project – Independent Consultant for the Part 12 and Potential Failure Mode Analysis for Brascan Power's Claytor Dam. Role as defined by the new FERC Part 12 process (Chapter 14 of FEG). Services included preparation of the Supporting Technical Information Document.

FERC Part 12 / PFMA, Walters Project – Facilitator for the Potential Failure Mode Analysis for Progress Energy's Walters Project. Role as defined by the new FERC Part 12 process (Chapter 14 of FEG).

Vice President - Technical manager for a group of thirty engineers, scientists, technicians, and geologist. Responsible for the work flow, engineering project management, and resource planning of the group. Group has completed a broad range of projects related to the FERC licensing and engineering support of hydroelectric facilities. Projects range include greenfield hydroelectric studies, modernization / upgrade studies, station condition assessment / due diligence, structural design, geotechnical evaluations, FERC hydro licensing, pumped storage siting and design, and hydraulics / hydrology. Managing an extensive dam safety program reviewing concrete and embankment dams.

PFMA Facilitator – Facilitator for the Potential Failure Mode Analysis for four conventional and one pumped storage hydroelectric project in North and South Carolina owned by Duke Power.

RAM_D – Completed RAM-D training session with a national group from the FERC. This included a workshop discussing and defining the FERC's Hydro Security Program. Completed a Risk/Security Assessment for the Cowan's Ford Hydroelectric Facility.

FERC Part 12, Georgia Power, North Georgia Projects – Assisted approved independent

consultant in the completion of the Part 12 inspection. Prepared drafts of IC reports, participated in field inspection, reviewed project documentation and reviewed project design documents.

FERC Part 12 / PFMA, Niagara Project – Independent Consultant for the Part 12 and Potential Failure Mode Analysis for AEP's Niagara Dam near Roanoke VA. Role as defined by the new FERC Part 12 process (Chapter 14 of FEG). Services included preparation of the Supporting Technical Information Document.

Lake Tahoma, North Carolina - Project manager for sedimentation evaluation study which includes sediment load measurements and calculations, evaluation of remediation options, and specifications for a sediment removal / disposal plan. Reviewed arch dam evaluation and developed revisions to low level outlet.

FERC Part 12 / PFMA, Gaston Shoals Project – Facilitator for the Part 12 Potential Failure Mode Analysis. Role is as defined by the new FERC Part 12 process (Chapter 14 of FEG). Also responsible for the preparation of the Supporting Technical Information document for this development. Project features includes three concrete gravity dams.

FERC Part 12 / PFMA, Wylie and Oxford Developments – Facilitator for the Part 12 Potential Failure Mode Analysis. Role is as defined by the new FERC Part 12 process (Chapter 14 of FEG). Also responsible for the preparation of the Supporting Technical Information document for this development. Project features includes concrete gravity dams, gated spillways and a rolled fill earth dam

Lakeview Hydro (PFMA) – Facilitator for the Potential Failure Mode Analysis for Ridgewood Energy's Lakeview Hydro in Colonial Heights, Virginia. Role as defined by the new FERC Part 12 process (Chapter 14 of FEG).

Saluda Hydroelectric Station, Greenville, South Carolina - Project Engineer for the stability and safety evaluation of the homogeneous earthfill West Embankment. Specified geotechnical investigation and completed static and liquefaction stability calculations.

FERC Part 12 Inspections - Owners representative for the performance of Part 12 Independent Consultant Inspections for eight FERC licensed projects in North and South Carolina. Developed technical information packages, participated in inspections, reviewed reports, and responded to Independent Consultant technical questions. Developed compliance plans following submittal of Part 12 reports.

Bad Creek Pumped Storage Station, Salem, South Carolina - Member of project design team for six years spanning initial design, construction, start-up, and operation. Activities and roles included:

- Developed environmental monitoring plan and conducted site audits. FERC license compliance.
- Structural design and architectural layout of construction infrastructure and site shop facilities.
- Miscellaneous civil siting tasks.
- Design of stream diversion system.
- Structural steel design of diversion pump structure.
- Geotechnical and hydraulic design of upper reservoir intake. Slope stability evaluation of existing slopes.
- Geotechnical final design responsibilities for three large earth dams.
- Responsible geotechnical engineer during the construction of the project zoned earth dams of over 13 million cubic yards.
- Test engineer for initial filling of upper reservoir. Developed controlled filling plan and led seventy person team monitoring dams and tunnels during start-up.

Catawba–Wateree Hydroelectric Project – Project Manager for FERC relicensing support for this 11 development project (825 MW). Support includes document preparation, strategic issue review, operational modeling and study planning. Serves as the only external member of the owners licensing core team.

Nantahala Hydroelectric Project – Project Manager for FERC relicensing support for seven projects. Support includes license application preparation, strategic issue review, operational modeling and resource studies. Serves as the

only external member of the owners licensing core team.

Completed inspections of the projects that include gravity, rockfill and arch dams.

Dillsboro Hydro, North Carolina – Completed a dam removal study defining the options, costs and FERC regulatory requirements associated with the decommisioning and dam removal of the Dillsboro project near Franklin, North Carolina.

Tillery and Blewett Falls, North Carolina – Project lead for the completion of a condition assessment study for these two 1920 vintage facilities with concrete gravity dams. Study scope included options for equipment modernization and an evaluation of the ability of the facilities to meet expected FERC license compliance provisions.

Nantahala Power, NC – Lead responsibility for the preparation and QC of seven FERC license applications currently in progress. Part of the strategic planning and program execution teams for these re-licensing efforts. Served as the group facilitator in a diverse stakeholder setting.

Progress Energy, NC - DTA lead for the Southeast region role in the relicensing of CP&L's Yadkin River hydroelectric facilities. DTA is the lead consultant for this ongoing licensing activity.

Duke Power Dam Safety Program - As lead civil engineer, conducted and/or managed the annual civil safety inspections at Duke Power Company's twenty-seven hydroelectric facilities. Completed inspection reports addressing structural and dam safety aspects including performance monitoring and recommendations for action. Projects include a diverse group of features including earth, gravity and arch dams.

Qinghai and Guangxi Province, China - Responsible for the technical evaluation of the 1,320MW Longyangxia and the 2,000MW Lijiaxia hydroelectric facilities in China including condition assessment of all project features including turbine-generators, concrete faced and zoned earthfill dams and powerhouse. Evaluated operational performance history and future operating regimes. Inspected and reviewed design and construction aspects of the 178 meter high Tianshengqiao concrete-faced rock shell dam.

Brazil Hydroelectric Development Minlas Gerias, Espirits Santo, & Paraguana States Brazil - Responsible for the technical evaluation of two operating hydroelectric stations in Brazil including condition assessment of all project features including dams and penstocks and development of life cycle costs. Reviewed and provided recommendations on greenfield feasibility studies.

Catawba River Projects, North Carolina – Program director for the evaluation, analysis and remediation of concrete water retaining structures at 13 hydroelectric developments on the Catawba River. Structure's require evaluation to determine compliance with current FERC regulations. Extensive remediation was required and is being provided on a turn-key EPC basis. Nine projects including dam strengthening and PMF remediation have been completed to date.

River Mountain Pumped Storage Project, Arkansas - Evaluated the civil conceptual design of this planned 800 Mw pumped storage facility. Components include intakes, dams, and site/infrastructure layout. Completed conceptual design modifications and developed cost and schedule information. Prepared Appendix A in anticipation of FERC license submittal.

Orange & Rockland Condition Assessment - Project Manager for a technical inspection and evaluation of the conventional hydroelectric assets Orange and Rockland Company. Led a multi-discipline team performing comprehensive technical evaluations, developing life cycle costs, and the determination of potential operations improvements.

West Coast Facility Assessment - Project Manager for a confidential technical evaluation for the pumped storage and conventional hydroelectric assets of a western US municipal utility. Led a multi-discipline team performing comprehensive technical evaluations, developing life cycle costs, and the determination of operations improvements.

Boulder Valley Pumped Storage Project, San Diego, County, California - Evaluated the civil conceptual design of this planned 800 Mw

pumped storage facility. Completed conceptual design modifications and developed cost and schedule information.

Chulaborn PS, Thailand - Part of an engineering team performing conceptual design studies for a 1200 Mw underground pumped storage facility in Thailand. Includes conceptual design of major civil features, layout of project infrastructure and layout of underground complex.

Alto Malema, Mozambique - Member of team which is performing feasibility study for the Alto Malema Hydroelectric Facility in northern Mozambique. Duties include the project site inspection/evaluation, assessment of dam siting, hydrology calculations, infrastructure planning, environmental and layout of major civil features. Specific technical studies include determination of the project design flood, evaluation of rainfall and streamflow data, and conceptual design of water control structures.

Lake Julia, Brevard, North Carolina - Developed Lake drawdown plan in support of the construction of a water intake. Completed erosion control plan and Lake level schedule. Performed condition assessment of the dam. Developed maintenance and safety evaluation plan.

ENEL Hydroelectric Stations, Nicaragua - Responsible for the technical evaluation of two operating hydroelectric stations in central Nicaragua including condition assessment of all project features including dams, powerhouses, spillways and water conveyance Developed life cycle costs for the operations and maintenance of the facilities. Established needs and schedule for future maintenance activities.

Mollejon Hydroelectric Station, Belize - Responsible for the technical evaluation of the 25MW Mollejon hydroelectric station in Belize including condition assessment of all project features including dams, spillways, roads and water conveyance along with development of life cycle costs. Performed comprehensive review of the project feasibility study for the Chalillo Hydroelectric Project proposed to be located on the Macal River upstream of Mollejon.

Niagara Mohawk Due Diligence - Project Manager and Technical Lead for a technical evaluation the 72 conventional hydroelectric station owned by NMPC. Led a multi-discipline team performing comprehensive technical evaluations, developed life cycle costs, and determined potential operational improvements.

Camp Summit Dam, Brevard, North Carolina - Completed dam safety inspection of rolled fill earth embankment and provided remedial recommendations for repairs and future monitoring.

Oconee Intake Dike, Seneca, South Carolina - Directed study of wet areas on the downstream slope of this homogeneous rolled-fill embankment. Directed geotechnical and laboratory investigations. Evaluated performance of internal drainage system and filters. Performed two-dimensional finite element seepage analyses and limit equilibrium stability computations.

New England Electric System - Completed initial assessment of NEES hydroelectric facilities being divested. Reviewed data room information and conducted site visits. Developed report in support of Phase I bidding defining condition, cost structure and proposal for revenue enhancements.

CESP São Paulo, Brazil - Leader of the technical due diligence team evaluating 21 hydroelectric projects with a total capacity of 11,000 Mw. Responsible for the civil and environmental condition assessments including the development of twenty year O&M and capital expenditure profiles. Completed dam safety evaluations including design reviews of multiple dam types and reviewed geotechnical monitoring data and programs.

Rhodhiss Hydroelectric Station, North Carolina - Geotechnical Engineer for a slope stability investigation of phreatic conditions in a homogeneous earth dam. Directed geotechnical field and laboratory investigations. Completed limit equilibrium computer model demonstrating adequate existing stability.

Keowee Hydroelectric Station, Seneca, South Carolina - Geotechnical Engineer for a slope stability investigation of phreatic and internal drainage conditions in a 100 feet high

homogeneous earth dam. Directed geotechnical / geophysical field and laboratory investigations. Completed limit equilibrium computer model demonstrating adequate existing stability.

Mulungushi & Lunsemfwa, Zambia - Project Manager and technical lead for a multi-discipline detailed due diligence of two 18 MW hydroelectric facilities being privatized in central Zambia. Developed condition assessment reports and complete cost planning for needed O&M activities. Evaluated hydrologic conditions and computed expected energy generation. Prepared O&M plan for takeover and future operation.

Seismic Evaluation - Hydraulic Fill Dams, North and South Carolina - Lead geotechnical engineer for the evaluation of six semi-hydraulic fill dams. Program includes seismic risk assessment for far-field and near-field (floating) earthquakes, field & laboratory investigations, and analysis for static and dynamic loading conditions.

Mills River Slope Stability, North Carolina - Performed limit equilibrium slope stability calculations for planned earth fill to support power substation. Evaluated laboratory soil parameter data and completed computer stability models.

Catawba Nuclear Station, South Carolina - Geotechnical Engineer for the evaluation of an expansion of the Stand-by Nuclear Service Water Pond Dam. Executed QA condition I calculations to determine the acceptability of a pool level increase.

Grandmother Lake Dam, Linville, North Carolina - Performed inspection of 50 foot high earth dam and adjacent spillway. Wrote inspection report and developed instrumentation and inspection program for performance monitoring approved by NC state dam safety department.

Laurel Valley Pumped Storage Project, Dunlap County, Tennessee - Project manager and lead engineer for the siting and initial layout of a 1500 Mw pumped storage station. Performed value-engineering studies to reduce project costs. Developed civil portions of the FERC preliminary permit application. Completing Exhibit A,B,C, and F of the FERC license including engineering layout, cost estimates, operations profile, and scheduling..

Mid-Columbia Hydro', Eastern Washington - Responsible for the technical evaluation six large hydroelectric facilities. Reviewed Part 12 dam safety reports, performed surveillance and reviewed project records. Completed due diligence report.

Irian Java, Indonesia - Performed a desktop review of the Ottomana Hydroelectric Feasibility Study assessing the civil conceptual design for a 100 Mw high head project. Responsible for final report covering multi-discipline review.

Santa Rita Hydroelectric Project, Peru - Evaluated energy production capability for a series of turbine sizing scenarios for this planned high head Pelton facility. Reviewed conceptual civil design for all structures including din dams and provided cost inputs for budgetary estimates. Developed energy models to evaluate capacity selection and hydrology.

Laleli, Turkey - Member of team which is performing a feasibility study for the Laleli hydroelectric facility in northeastern Turkey. Duties include the complete project site inspection/evaluation, assessment of dam siting, hydrology calculations, operational and energy modeling, O&M planning, infrastructure planning, environmental and layout of major civil features. Specific technical studies include determination of the project design flood, evaluation of energy production, evaluation of rainfall and streamflow data, and conceptual design of water control structures and dams.

Reynolds Creek Pumped Storage Project, Dunlap County, Tennessee - Civil engineer for the siting and initial layout of a 1000 Mw pumped storage station with an underground power complex. Developed civil portions of the FERC preliminary permit application. Completing Exhibit A,B,C, and F of the FERC license.

Murray Hydroelectric Station, Little Rock, Arkansas - Civil Engineer responsible for the evaluation and recommendations of underwater concrete repair of the spillway training wall. Developed procedure and made product recommendations.

Buzzard Roost Hydroelectric Station, Greenwood, South Carolina - Geotechnical Project Engineer for the investigation of an alluvial sand zone in the foundation of the project earth dam. Specified requirements for field and laboratory testing. Evaluated liquefaction potential of material in question using Seed/Berkeley criteria.

Jocassee Hydroelectric Station, Seneca, South Carolina - Geotechnical Engineer for a slope stability investigation of phreatic conditions in a 350 feet high zoned rockfill earth dam. Directed geotechnical field and laboratory investigations. Completed limit equilibrium computer model demonstrating adequate existing stability.
Project Engineer for civil aspects of the modernization program at this pumped storage facility.

Wylie Hydroelectric Station, South Carolina - Geotechnical Engineer for a slope stability investigation of phreatic conditions in a 100 feet high homogeneous earth dam. Directed geotechnical field and laboratory investigations. Completed limit equilibrium computer model demonstrating adequate existing stability.

Holidays Bridge Hydroelectric Station, Anderson, South Carolina - Geotechnical Project Engineer for the elevation of the stability of a earth canal dike. Completed stability calculations, supervised field and laboratory testing , and specified follow-up monitoring program.

Technical Papers / Presentations

"The Bad Creek Dam Design", Luttrell, E.C., United States Committee on Large Dams Conference, Charlotte, N.C., 1987.

"Hydroelectric Generation at Duke Power Company", Luttrell, E.C., presentation to the North Carolina Professional Engineers, October, 1992.

"Remedial Grouting Using Responsive Integration at Jocassee Dam", Luttrell, E.C., Bruce, D.A., and Starnes, L.J., Association of State Dam Safety Officials National Conference, Kansas City, Mo., 1993.

"The Automated Instrumentation Monitoring System at the Bad Creek Project", Luttrell, E.C., American Society of Civil Engineers, WaterPower '93, Nashville, 1993.

"Duke Power Company's In-House Dam Safety Program", ASDSO Southeastern Regional Meeting, UNCC, 1994.

"Remedial Grouting at Jocassee Dam", Luttrell, E.C., Bruce, D.A., and Starnes, L.J., *Ground Engineering*, 1994.

"Technical Evaluation of Hydroelectric Facilities in Peru", Luttrell, E.C., Grady, D.R., and Diaz-Molina, I., American Society of Civil Engineers WaterPower '95, San Francisco, 1995.

"Seismic Investigation Of Wateree Dam", Luttrell, E.C., Sams, C.E., and Starnes, L.J., Association of State Dam Safety Officials Annual Conference, Atlanta, 1995.

"Mozambique: A Feasibility Study for Hydroelectric Development", Luttrell, E.C., Grady, D.R., and Diaz-Molina, I., American Society of Civil Engineers WaterPower '97, Atlanta.

"Buying and Selling Hydro Assets: Project Due Diligence", Luttrell, E.C, HydroVision '98, Reno, Nevada

"The Road Well Traveled: Technical Due Diligence and Asset Integration", Luttrell, E.C. and Grady, D.R., Hydrovision 2000.

Representative Project Inspection Experience
Ed Luttrell, PE

		Inspection Role							Dam Type / Additonal Features										
PROJECT / DEVELOPMENT	CLIENT	Part 12D IC / Report Preparation	PFMA Facilitator	Owners Part 12D Engineer	State Inspection	Condition Assessment	Annual Safety Inspection	Prepared STI	Concrete Gravity	Concrete Arch	Slab and Buttress	Homogeneous Embankment	Zoned Embankment	Hydraulic Fill	Penstock	Tunnels	Pumped Storage	Radial Gates	Vertical Spill Gates
Saluda	South Carolina Electric & Gas	X						X						X				X	
Jocassee	Duke Power		X					X					X			X		X	
Wateree	Duke Power		X					X						X					
Ninety-Nine Islands	Duke Power		X					X	X										
Cedar Cliff	Nantahala Power							X					X					X	
Pinnacles	City of Danville	X						X		X					X	X			
Yellow River	Alcoa					X				X			X		X	X		X	
Castalc	Louis Dreyfuss												X			X	X		
Bryson	Nantahala Power			X					X										
Grandmother Lake	GLD Corp				X							X							
Bad Creek	Duke Power						X						X			X	X		
ElectroLima	DEI					X			X				X		X			X	
Mission	Nantahala Power			X							X								
Niagara	AEP	X						X	X						X				
Lookout Shoals	Duke Power		X					X	X										
Rocky Creek / Cedar Creek	Duke Power		X					X	X									X	
Bear Swamp Pumped Storage	Brascan	X						X					X		X		X		
Tillery / Blewett Falls	Progress Energy					X			X					X				X	

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Tahoma	LTHA				X					X									
Bath County Pumped Storage	Dominion Energy		X																
Claytor	AEP		X																X
Tuxedo	Duke Power				X					X					X				
Lakeview	Ridgewood Energy		X								X								
North Georgia (5 developments)	Georgia Power	X							X	X		X			X			X	
Bear Creek	Nantahala Power			X				X	X									X	
Thorpe	Nantahala Power			X				X					X					X	
Nantahala	Nantahala Power		X					X					X		X			X	
Mollejon	DEI					X						X							
Wylie	Duke Power			X			X					X							X
Walters	Progress Energy		X							X						X		X	
Fishing Creek	Duke Power		X					X	X										X
Bridgewater	Duke Power		X					X					X			X			
Buzzard Roost	Duke Power			X			X							X					
Keowee	Duke Power			X			X					X							
Paranapanema	DEI					X			X						X			X	
Camp Summit	DuPont Chemical				X		X					X							

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		Inspection Role							Dam Type / Additional Features										
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Gaston Shoals	Duke Power		X				X	X	X										
Oxford	Duke Power		X					X	X										X
Wylie	Duke Power		X				X	X	X			X							
Thorpe	Nantahala Power		X					X					X		X	X		X	
Tuckaseegee	Nantahala Power		X				X	X		X									
Great Falls/Dearborn	Duke Power		X					X	X										
Parr	Scana-SCE&G	X						X					X					X	
Fairfield	Scana-SCE&G	X						X				X			X		X		